

Human-in-the-Loop Simulation for Airway Facilities Operations

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Abstract

The author describes an Airway Facilities (AF) simulator for human-in-the-loop research and training. The AF simulator is a flexible, self-contained system. A simulator of this type and complexity is unique in the realm of human-in-the-loop simulation. It can be used as a platform for scientific research in human factors concepts, testing and validation of behavioral and performance measures, and as a potential training tool. The self-contained nature of the simulator allows for increased experimental control of research and generalizability of results. Because the system is self-contained, it is portable.

This document provides an overview of the system components that comprise the AF simulator. The author proposes various performance and behavioral measures and discusses the potential for use of the AF simulator as a training platform.

Introduction

In the realm of air traffic control (ATC), researchers have measured human performance and behavior using computerized, high-fidelity simulations. Researchers have used these human-in-the-loop simulations to study the impact of numerous proposed changes to the ATC system such as dynamic resectorization, shared separation, and the use of new automation tools. This prior ATC research serves as a foundation for the growth of research in AF, promoting a better understanding of performance capabilities and limitations of AF Specialists.

AF is a vital part of the United States' National Airspace System (NAS). AF provides the foundation upon which Air Traffic Control Specialists and pilots rely upon to move aircraft efficiently. The goal of the current project is to develop a means to improve our understanding of human behavior in AF. Researchers have conducted very few empirical studies of AF Specialist behavior and therefore our knowledge is quite limited. For example, AF Specialists possess expertise in both technical systems and geographical domains. Researchers could use the AF simulator platform to assess the value of different types of expertise

and determine how to best capitalize, or further develop, types of expertise.

The AF simulator is a flexible platform that researchers can use to examine theoretical concepts and develop measurement techniques; however, it can also serve a more practical purpose. The self-contained nature of the AF simulator makes it a useful platform for training because operational facilities are not involved or jeopardized. Training has recently taken on new significance since the transition to centralized AF remote maintenance and monitoring in OCCs. The staff of these newly formed OCCs consists, in part, of AF Specialists who were once AF field technicians. The transition to OCCs places new requirements on these AF Specialists to develop new skills. In addition to remote maintenance and monitoring, OCC Specialists will be required to perform remote control of facilities in the near future. This remote control capability allows the OCC Specialists to perform preventative and corrective maintenance on a facility without having to send an AF field technician to the site. However, many of the OCC Specialists are unfamiliar with this task. Although they have performed remote maintenance in the past, they were accustomed to equipment and graphical user interfaces (GUIs) that differ significantly from the GUI provided by MASS. Training on MASS will be essential to timely success in performing remote maintenance and control in the near future. The AF simulator can provide the means necessary to train and prepare the OCC Specialists to perform their job more efficiently.

To address the goal of obtaining a better understanding of AF specialist behavior and to improve skills where necessary, an Engineering Research Psychologist from the NAS Human Factors Group (ACB-220) of the William J. Hughes Technical Center, along with a team of software engineers, is developing a high fidelity, human-in-the-loop AF simulator to examine human performance and behavior in AF Operations Control Centers (OCCs). The developers have constructed the AF simulator so that its operation is completely contained within the Federal Aviation Administration (FAA) Research Development and Human Factors Laboratory (RDHFL). Such a self-contained simulator will allow complete experimental control of simulation activity

without sacrificing usefulness or flexibility. By creating a self-contained simulator, researchers can eliminate the need for large, expensive equipment such as the Tandem Maintenance Processor System (MPS) that AF Specialists currently use in actual operations. It will also eliminate the need to rely on third-party personnel to run the simulations. Furthermore, a self-contained simulator is portable and can be used at any location.

Simulator Components

The AF simulator components are representative of current AF operations. Major software applications used in the simulator are the Event Manager (EM), the Maintenance and Automation System Software (MASS), and a weather display. Figure 1 shows a photo of the user workstation. An associated Communication System, Event Recorder and Event Analyzer, are also included to provide researchers or other users a means of assessing performance and behavior. The following text describes each of these components.



Figure 1. The AF simulator workstation. From right to left: Weather display, EM, MASS.

Event Manager

AF Specialists use the EM software application to schedule, track, and coordinate all events of concern. The EM processes events such as unscheduled outages, preventative maintenance, radio frequency interference, aircraft accidents and incidents, and flight checks. EM is also linked to the Maintenance Management System (MMS) that provides record keeping and national reporting capabilities.

The AF simulator emulates the capabilities of both EM and the associated MMS. The design of the EM emulates field operations as realistically as possible. Therefore, EM is fully functional with only a few exceptions. EM contains numerous functions but this document describes only the primary functions. EM comprises six main pages: Events Display, Interruption Entry Form, Event Coordination

Form, Coordination Info, Facility Info, and Phone Book Sheet. Each of the pages rely on one or more databases that are stored and maintained on a server using Microsoft® Structured Query Language (SQL) 7.0. A brief description of each EM page and their primary functions appear next.

The Events Display page shows a list of each event that an AF Specialist has entered into EM. For each event, the information identifies the facility name, facility type, start and end date and time of the event, status, log interrupt report (LIR) category and condition, reporting level, a brief summary, and the group assigned to perform the event. Users can sort and filter the information on the Events Display page as needed. The Events Display page also allows the user to set refresh and alarm latencies. The refresh function determines how often the Events Display updates to reflect any new events that are created or any updates to existing events. The alarm function alerts the user whenever a scheduled event is about to occur but that the user has not performed the final coordination.

Users can create or update an existing event ticket by completing the Interruption Entry Form. Users specify information such as the facility of concern, event information (e.g., MMS LIR code category, start and end date and time, event impact, and event status), assign an AF technician to the event, and record written information about the event. When the Interruption Entry Form is active, users can also send an electronic page to the assigned Specialist as a means of communication about a specific event.

Users enter the Event Coordination Form to assist them in performing event coordination and to record information about the coordination. Once the user provides a facility identification and type, the Event Coordination Form will present the appropriate points of coordination and telephone numbers to the user. The user can indicate if it is an initial, final, or return to service coordination. They can also record the initials of the person with whom they coordinated and the time they performed the coordination. The user can call each point of coordination by simply clicking the mouse on the telephone numbers provided.

Users enter the Coordination Info page to establish new services and points of coordination for each facility. The user may create both outage coordination points and general coordination points. Once created, the coordination points and their telephone numbers appear in the Event Coordination Form.

The Facility Info Form provides two important functions. First, it provides a database for facility-specific comments. Users can edit and search this database, as needed. Second, it provides a facility relationship table. Users can gain information from this table to learn what facilities are related to one another. This is a very important function because users can become aware of redundant and backup facilities and services that they should not intentionally take out of service while the primary system is

receiving maintenance. The Facility Info page also provides buttons to obtain street map and weather information near a specified facility. The weather and map functions are not available in the AF simulator because they rely on real locations that may or may not be used depending on the purpose of the simulation.

The Phone Book Sheet provides a list of points-of-contact and technicians and provides primary and alternate phone numbers (when available) for each listing. Users can sort the data by point-of-contact name or type (e.g., flight service station, power company, and air traffic control tower). Users can also search the data by service name or by technician last name to help locate needed information.

Maintenance and Automation System Software

AF Specialists use the MASS application to remotely monitor and control facilities and subsystems that are integrated into the Remote Maintenance Monitoring System. The MASS displays alarms, alerts, and status changes of subsystems. Using MASS, a user can acknowledge alarms and alerts and monitor subsystem status, configuration, performance, and environmental data. A user can also use MASS to remotely adjust subsystem configurations and diagnose problems. A user can also view subsystem states and issue remote commands to alter those states and return a facility to service.

Within the AF simulator, users can implement scenario scripts to simulate data being sent and received from remote facilities to MASS. Scenario scripts can contain time-based events that result in changes to the MASS database, thereby simulating changes to a facility that result in alarms, alerts, or status changes. A user of the AF simulator can easily construct scenario scripts with unique scenario and user wizards. User interaction with the complicated MASS databases is not required as the wizards accomplish database manipulation automatically. Additionally, a user can easily create the domain to be simulated via the wizards by selecting the type and number of facilities of interest. This high level of flexibility and ease of use has been accomplished because MASS, as constructed within the AF simulator, operates via a customized Microsoft® SQL server and does not require any of the cumbersome and expensive hardware used in actual AF field operations.

Weather Display

Weather can adversely affect AF operations and hinder the ability of AF field technicians to perform preventative maintenance and repairs. One might expect that AF Specialists would use weather information to inform them when to take preventative measures and to make decisions about dispatching AF field technicians in severe conditions. However, it is not clear how, or if, AF Specialists actually use weather information. The AF simulator is able to

incorporate weather into the scenarios to increase realism and to gain a better understanding of how weather may affect AF Specialist performance. Weather information can also provide knowledge that may allow an AF Specialist to take more effective and timely steps to avoid or repair an outage.

The weather display in the AF simulator is comparable in appearance to the current Weather and Radar Processor application. The display provides past and current (i.e., trend) information about weather affecting the simulated domain. A “looping” display of simulated weather superimposed over a map of the AF domain provides weather trend information.

Measuring Performance and Behavior

Currently, there are no established methods for measuring behavior, workload, task performance, or situation awareness in AF simulations. The development of a realistic AF simulator allows researchers to develop valid and reliable measures that they can use to examine current and future maintenance concepts. The current project begins the development process by implementing numerous measures within a high-fidelity AF simulation. Table 1 shows a list of candidate measures sorted by type.

Researchers will gain information regarding the usefulness, reliability, and validity of these measures as they implement them. Using the simulator, researchers can identify the most appropriate measures or modify existing measures for use in the AF simulation environment. A better understanding of the measures will emerge as researchers use them over a number of studies. The AF simulator provides a means through which researchers can develop, test, and validate these measures over time.

Event Recorder and Analyzer

Software engineers at the RDHFL have integrated the Event Recorder software in a modular fashion with the EM software application. The Event Recorder software tracks all user activity, and a researcher can analyze any subset of this activity using the Event Analyzer software. The Event Recorder software allows researchers to measure the frequency and duration of user interaction with the EM and its various components. The Event Recorder software creates data files that researchers can use in the Event Analyzer software. Using the Event Analyzer software, researchers can calculate and obtain summary information about user behavior and performance. For example, researchers can use the Event Recorder and Event Analyzer software to determine how much time was spent on a particular page, how many times a button was pressed, how many times a database search was performed, or how long it took a user to acknowledge a MASS alarm or alert.

Communication Activity

AF Specialists rely heavily on telephone communication to perform their job. The AF simulator includes Communication System software to simulate and measure telephone communications. Users of the AF simulator make and receive calls using this Communications System software, which is transparent to them. To place a telephone call, the user mouse clicks on a displayed telephone number. Once the user places the call, a message appears on a remote computer monitor staffed by either a researcher or a Subject Matter Expert (SME). The message provides notification of whom the user is calling. The researcher or SME, simulating points-of-contact, can then answer the phone as the appropriate person that the user is calling. An open telephone line is present to allow voice communication. Users can also send text page messages to a point-of-contact (simulated by a researcher or SME) using the EM. The SME or researcher can also place calls to the user through the Communications System software. Through a series of button presses made by a researcher or SME, the Communication System software collects data regarding the number of calls made, how long it took the user to answer each call, and the duration of each call. These data are then available for later analysis as needed.

	Subjective	Objective	Performance	Taskload	Workload	Situation Awareness
SME Rating	X		X		X	X
Time to contact field technician		X	X			
Time to rectify MASS alarm		X	X			
Time to rectify MASS alert		X	X			
No. of telephone calls made		X		X		
No. of telephone calls received		X		X		
No. of MASS alarms		X		X		
No. of MASS alerts		X		X		
Duration of telephone calls made		X		X		
Duration of telephone calls received		X		X		
ATWIT rating	X				X	
Post-scenario questionnaire	X		X		X	X
Time to answer incoming telephone calls		X			X	
Situation Present Assessment Method		X				X
Time to acknowledge MASS alarm		X	X			X
Time to acknowledge MASS alert		X	X			X

Table 1. Candidate metrics for use in the AF simulator.

Taskload

Researchers can measure taskload several ways based on the number of actions that a user performs during a given period. A count of the number of incoming and outgoing telephone calls placed via the Communication System software provides one objective estimate of taskload. Researchers can also measure taskload by recording user interaction with the EM and MASS via the previously described Event Recorder and Event Analyzer software. The number of alarms and alerts that a user receives via MASS can also serve as an objective indicator of taskload.

Subjective Workload

When using the AF simulator for research purposes, subjective ratings of workload can complement objective taskload measures. Subjective workload can be measured a number of ways using either on-line techniques such as the Air Traffic Workload Input Technique (ATWIT) (Stein 1985) or off-line techniques like the NASA-TLX (Hart and Staveland 1988). Although not yet tested, there is no reason to believe that an on-line measure of subjective workload like ATWIT would interfere significantly with the fidelity of the AF simulator in general or a simulation in particular.

Performance

Researchers can measure user performance within the AF simulator by using any number of objective or subjective metrics. Researchers can automatically obtain objective performance metrics from the Event Recorder and Event Analyzer software that is part of the AF simulator. Such objective performance measures include time-based measures such as mean time to acknowledge an alarm or alert, mean time to call an AF technician during an unscheduled outage, and mean time to complete an event ticket. An SME can use observation to record errors, which are indicators of degraded performance because an SME is the most likely person to notice when an error occurs. An SME can also provide subjective performance metrics based on his observations of the user during each scenario.

Situation Awareness

Although there is no direct relationship between performance and situation awareness, researchers may consider some performance measures as secondary indicators of situation awareness. For example, the time it takes a participant to acknowledge an alarm or alert may predict situation awareness. Researchers can use direct measures of situation awareness as well. To maintain realism of a simulation and to prevent interruptions, the author has in a previous report (Truitt and Ahlstrom 2001) recommended using the Situation Present Assessment Method (SPAM)

(Durso et al. 1998; Willems and Truitt 1999) to collect an objective measure of situation awareness. The SPAM operates by posing yoked queries and then measuring response time to those queries. Queries focus on present visual data, present conceptual data, and likely future occurrences. A researcher presents the SPAM queries using normal means of communication such as the Communication System software and telephone in the AF simulator. Therefore, the SPAM does not interrupt or change the task significantly. The SPAM queries are interspersed with other telephone calls to prevent the user from expecting when SPAM queries will occur. The author recommends that the researcher develop all queries with the assistance of an SME to ensure that queries refer to information and relationships that are relevant to the ongoing scenario.

Conclusion

Overall, the AF simulator will further the progress in the AF domain in terms of both conceptual research and practical training. Researchers can develop, test, and validate measures over time while conducting high fidelity, human-in-the-loop simulations. For the first time, human factors researchers will have a realistic platform to conduct a systematic program of study regarding human performance, capabilities, and limitations in the AF environment. Current AF Specialists in the OCCs can also use the AF simulator to complement their skills in remote maintenance monitoring and control.

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